Iron-Polyethylene Combination for Shielding of 14 MeV Neutrons

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Abstract

The best way to a chive good shielding of 14 MeV neutrons was investigated. The idea is to thermalize as many neutrons as with a given shielding thickness. Since hydrogenous material is not efficient for thermalization of 14 MeV neutrons, the neutrons are first slowed down with iron to energy rang where hydrogen is more efficient for thermalization. Layers of iron and polyethylene of various thicknesses that add up to 20 cm were investigated and it was found that a composition of 10 cm of iron before 10 cm of polyethylene gives the highest number of thermal neutrons. The fast neutron flux leading out of the shielding is decreasing continuously with increasing iron thickness.

توليف حديد - بولي أثيلين لتدريع نيوترونات ذات الطاقة 14 مليون إلكترون فولت

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الخلاصة

لقد استقصيت أفضل طريقة لمعرفة الدرع الجيد لنيوترونات ذات الطاقة 14 مليون إلكترون فولت. الفكرة في ذلك تكون بتبطئة أكبر عدد ممكن من النيوترونات لسمك الدرع المأخوذ. طالما ان المواد الهيدروجينية تكون غير كفوءة في الحصول على النيوترونات الحرارية من النيوترونات ذات الطاقة 14 مليون إلكترون فوات لذلك تبدأ النيوترونات ذات الطاقة 14 مليون إلكترون فولت أولا في الحديد الى مدى طاقي يكون فيه الهيدروجين كفوء جدا للحصول على النيوترونات الحرارية . لقد تم أخذ صفائح من الحديد والبولي اثيلين بسمك مختلف (يصل الى 20 سم) فوجدنا ان 10 سم من البولي أثيلين خلف 10 سم من الحديد يعطي أعلى فيض نيوتروني حراري .كما وجدنا أيضا ان فيض النيوترونات السريعة النافذة من الدرع تقل باستمرار عند زيادة سمك صفائح الحديد الى الدرع

1. Introduction

During the last decade, neutron generators have found widespread use in various types of physical, chemical and biological researches.

The application of high yield fast neutron generators involves a health physics problem because no price experimental data on shielding properties of various materials are available [1, 2]. The shielding of 14 MeV neutrons has been a problem in the design and construction of laboratories where a D-T neutron source was used. The importance of this problem is emphasized by the number of papers published in this subject. For example, *Broerse et al.(*1966) [3], *Hake* (1969)[4], *Maruyama et al.*(1972) [5], *Csikai et al.* (1984, 1985)[6,7], *Varadi et al.* (1977,1988) [8,9] and others [10-18].

Generally, fast neutron shielding is done first by thermalization and then absorption of neutrons by an absorber of high cross section in thermal region. The main problem in the shielding of 14 MeV neutrons is that it cannot be thermalize easily by hydrogen because the cross section of this energy is very low (0.66 barn)[1].

In order to have an efficient shielding, a stage must be added in the slowing process that will reduce the neutron energy to a range where hydrogen is more efficient for thermalization. This intermediate slowing down can be done by inelastic scattering with a heavier element [1, 2].

Such an element which proved satisfactory is iron, the cross section of iron is relatively high of order of a few barns and its value at 14 MeV is about 2.5 barn [1]. Iron is also a common construction material relatively cheap and easy to handle.

In the present work, the shielding of a given thickness (20 cm) was investigated for the combination of an iron layer and polyethylene layer that provides the best shielding for the 14 MeV neutrons.

2. Experimental details

The schematic diagram of the experimental arrangement used for the present measurements is shown in Fig.1.

Neutron Generator type T- 400 was obtained from Iraqi Atomic Energy Commission. This generator accelerates deuterons with energy of 100 KeV. The deuterons impinge on a target which consists of tritium absorber in titanium layer. Neutrons were produced by $^3_1H\,(d,n)\,^4_2He$ fusion reactions on a target. The neutron energy that emitted in zero direction to incident deuteron beam (in forward direction) was 14 ± 0.1 MeV and the source strength was 10^8 neutron/sec.

The samples of iron and polyethylene were putted in the form of rectangular plates with dimensions 60cmx60cm. Samples were placed near the neutron generator target. So that the target was placed at the center of the face and the total width of the shield was 20 cm.

In such a way, starting with 20cm of polyethylene, the iron layer thickness was increased from 2 cm to 20 cm in the steps of 2 cm and polyethylene layer was decreased from 20 cm to zero cm in the steps of 2 cm gradually keeping the total thickness constant (20 cm).

Three neutron measurements were made during each step. One fast neutron measurement was made at the target for normalization to constant source intensity. The other two detectors were detected the fast and thermal neutron fluxes behind total shield thickness. The fast flux on both sides of the shield was measured by liquid organic scintillation detector type NE213 manufacturer Nuclear Enterprise Ltd. Neutron spectrometer containing an assembly of NE213 detector, pre-amplifier, amplifier, power supply and computerized multichannel analyzer (MCA) was used to measure the fast neutron intensities.

Each detector was placed inside a shield having 25cm deep cylindrical collimator with a diameter of 8 cm which used to (paraffin wax) avoid the effect of scattered neutrons from reaching to the detectors.

The thermal neutron flux was measured with 25 cm long, 3cm diameter BF_3 detector.

Each spectrum was recorded for sufficient long time to reduce the statistical error less than 3%, this error is shown in error bar of the measured results (figures 3 and 4). Background spectra were recorded for the same time and subtracted from each spectrum.

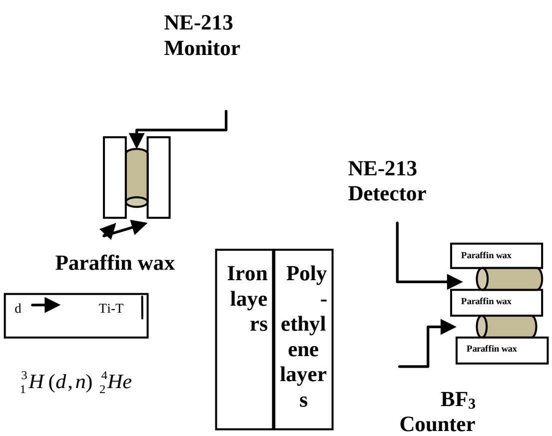

Fig 1. Geometrical arrangement of the experimental measurements.

3. Results and discussion

The measured results are shown in figures (2 – 4). Fig. 2 shows accumulate spectrum on the MCA of the NE-213 detector. It is seen that the iron has more attenuation of 14MeV neutrons than polyethylene at the same thickness and the neutron flux in 14MeV region is decreasing with increasing neutron energy.

The measured thermal flux outside the shielding is shown in figure 3 starting with 20 cm of polyethylene, the number of thermal neutrons is increased because there are more neutrons slowed down from 14MeV to the 2 MeV region (or below) and have a chance to be thermalize in the polyethylene. The maximum thermal neutrons are obtained with about is 10 cm of iron. After that, when the iron layer thickness is increased and the polyethylene layer thickness is decreased, the thermalization possibility is lowered so that the thermal neutron flux decreased.

The fast neutron distribution is shown in figure 4. The fast neutron flux resulted from the shielding is much less affected by the iron layer thickness than the thermal neutron flux. The thermal neutron flux increased three times by replacing the 10 cm of polyethylene with iron (see figure 3).

The fast neutron flux decreased continuously and its value with 20 cm of iron is about one half of it's with 20 cm of polyethylene (see figure 4).

4. Conclusions

The main goal of this work was to find a way to thermalize many 14 MeV neutrons as possible with a relatively thin shield thickness.

The neutron thermalization that could be obtained by the combination of 10 cm of iron as a first medium and 10 cm of polyethylene was about three times higher than that obtained with 20 cm of polyethylene.

The thermal neutron flux could be stopped by any thermal neutron absorber. It is also interesting to note that when a layer of few cm of iron is used as a first medium, a significant of thermal neutrons could be obtained.

The amount of fast neutrons decreased continuously with increasing iron layer thickness.

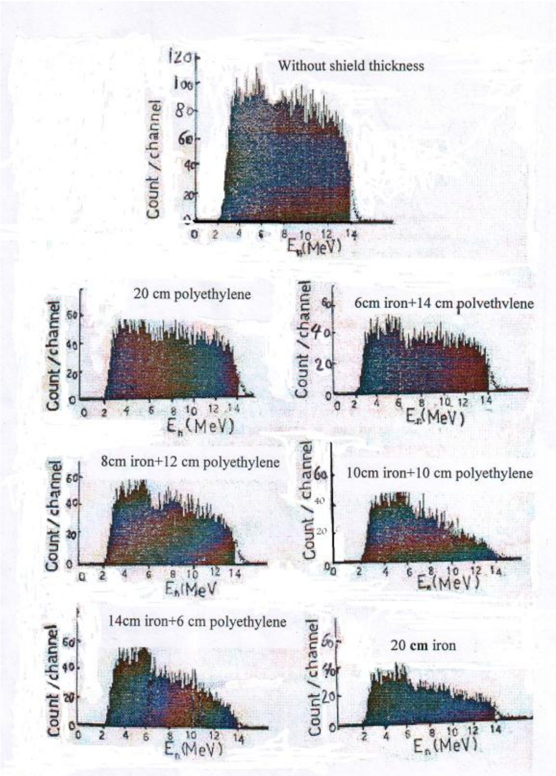

Fig. 2. Neutrons spectrum measured by fast neutron detector NE-213 ,Where E_n is neutron energy.

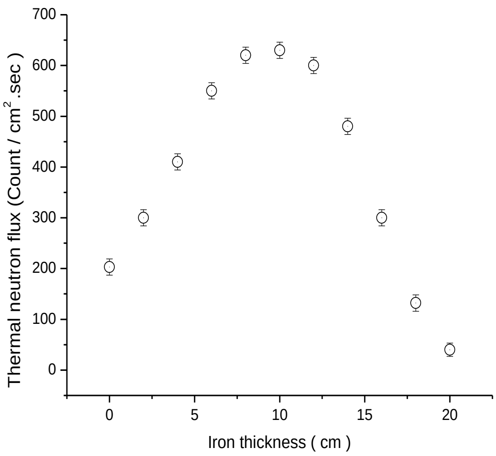

Fig. 3 Thermal neutron flux distribution.

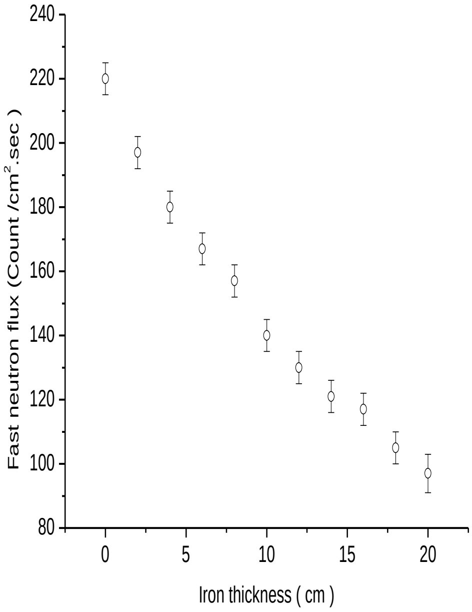

Fig.4 fast neutron flux distribution.

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